CORNELL RURAL SCHOOL LEAFLET

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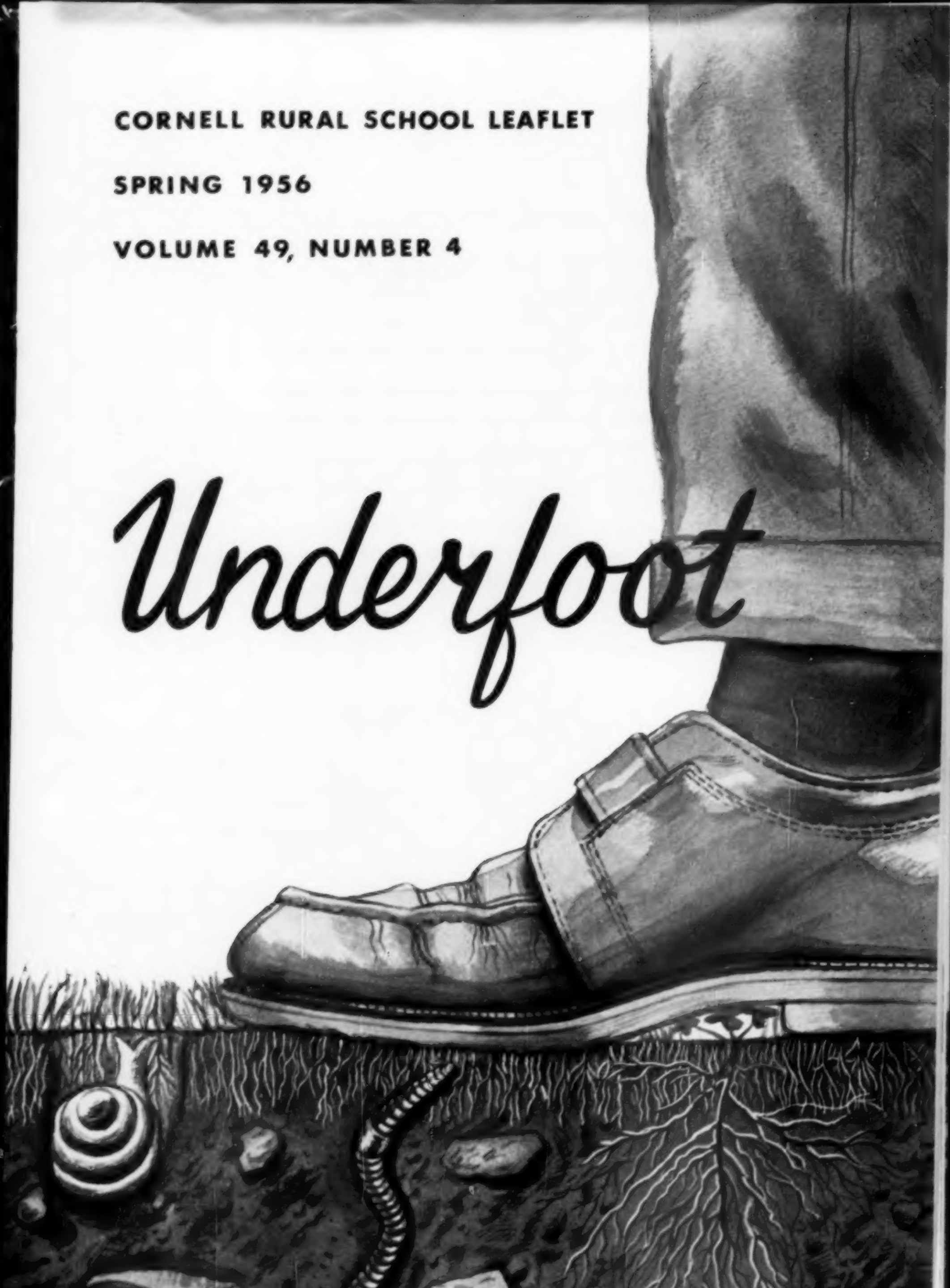
Underfoot



CORNELL RURAL SCHOOL LEAFLET

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UNDERFOOT

By Dora E. Worbs and Eva L. Gordon

Wherever you are now, down underfoot there is soil or the rock from which soil is made. This soil is not just plain dirt. It is an exciting world which few persons really discover. It is a living world of plants and animals—some so small that they can be seen only with the help of a microscope, others as large as woodchucks and the roots of giant trees. It is a world of particles of different colors, sizes, and combinations. It is a chemical world of air, water, and minerals. It is a constantly changing world, a wonderful world to explore.

Exploring Soils

Of course you already have had many experiences with soil. Perhaps you made mud pies when you were little. You may have waded in a puddle after a rain and enjoyed the cool squish of mud between your bare toes, or scuffed along a dirt road on a warm day and felt the puffs of fine dust. You may have learned where to dig earthworms for fish bait. Or you may have planted seeds and cared for growing plants. Perhaps you have noticed that some soil is dark colored and some is light. Can you remember some experiences that helped you to learn about soil and how soils differ?

A Handful of Soil

Let's look at a handful of dry soil. Spread a little of it in the palm of one hand. What can you see? tiny pebbles? lumps that you can break into smaller pieces? grains of sand big enough to be seen and felt? fine dust? small bits of plants?

What colors are these different things? In New York State most soils are made up largely of gray or brown or blackish particles,

Particles of many sizes make up a handful of soil

but this would not be true everywhere.

When you have discovered what you can, spread your sample of soil on a sheet of white paper. Look at it with a magnifying glass if you can get one. Can you see particles of different sizes, shapes, and colors? What else can you discover? Did some of the fine dust cling to your hand instead of falling on the paper? How does this dust feel when you rub it with your finger?

Next, slide the loose soil from the paper into a container. Tap the paper to remove all the soil that you can. Isn't the paper "soiled"? Rub a clean finger or a piece of facial tissue over a dirty place on the paper. Does some of the dirt rub off? Look at a soiled spot with your magnifier. You may not be able to see separate soil particles even with its help.

Most surface soils are much like the soil you examined. They are mixtures of particles of many sizes, but the proportions of large and small particles vary in different soils. There may be *pebbles* or even large stones. Usually there are *sand* grains large enough to be easily seen—you can learn more about their shape if you have a magnifying glass to help you. There are fine *silt* particles too small to be seen with the naked eye as separate particles, but you can see them with the help of an ordinary microscope. There are also *clay* particles that are even smaller than silt. You would need a special kind of microscope to see them.

Most of the particles you see in a handful of soil are broken-up bits of rock made up of various minerals. But some may be the remains of plants and animals that have lived and died in or on the soil. Perhaps you saw bits of leaves or roots or part of a dead insect. Such materials become fine soil particles called *humus*. You can learn more about humus on pages 8, 25, and 26 of this Leaflet.

Comparing Soils

Collect samples of surface soils from around your school and your homes. Dig under a bush, in the edge of a lawn, along the wall of a building, or at the foot of a slope. Take soil from a plowed garden or field, from under fallen leaves in a woods, along a stream bank, or even on a sidewalk after a hard rain. Try to get other samples from about a foot below the surface.

Put each sample into an ordinary letter envelope, an ice-cream cup, or some other container. Write on the container the name of the place where you found the soil; for example: in the garden, at the bottom of the ditch along the road, at the top of the hill behind the school, and so on.

Examine these samples as you did your first handful of soil. What differences can you see? Were some samples made up largely of coarse particles, and others of fine, powdery materials? Were some loose and crumbly, others lumpy or cloddy? Did you find soils moist enough to dampen the paper on which you put them? Can you roll some of the damp soil into balls or "snakes"?

Return each sample to its container when you have finished looking at it so that you can use it again.

The Feel of Soil

Most soils, you remember, are mixtures of particles of different sizes—coarse sand, fine sand, silt, and clay. But the proportions of large and small particles vary in different soils. Soil scientists learn much about these differences just by feeling. Can you feel differences in your soil samples?

Rub a little of each sample between your fingers. Do some of them feel gritty? A gritty feeling tells you that sand grains are a prominent part of *those* soils. Silty soils feel like flour or talcum powder when they are dry and make smooth, slippery mud when they are wet. Clay soils

Below last year's leaves humus is being made

have enough clay particles to give them a harsh feeling if they are dry and to make them sticky if they are wet. Write on each container a word or two to tell how you think the soil in it felt: gritty, floury, slippery, harsh, sticky. (You may use other words than these.)

As you tested the "feel" of your soils you probably discovered that some of your samples were drier than others. Try to make all of them about equally damp by sprinkling them with water. You may need to crumble some samples. Your samples should be moist enough so that in most of them particles will stick together when you press a bit of soil between your fingers, but no water will drip out.

Then roll a ball of each soil about an inch in diameter between your thumb and forefinger or in the palm of your hand. You may need to experiment to make your samples just wet enough to roll well. Try to make each ball into a "snaky" roll; then put it on or near its labelled container. Place together all the samples that make smooth, sticky rolls which keep their shape well. They are probably *clayey* soils. Have you some rolls that crack in several places? *Silty* soils make rolls like that. Perhaps you have some *sandy* soils that do not stay together enough to make even a small "worm". You may find *sandy silt* that rolls a little better than sand but not so well as silt; or a *silty clay* which is between silt and clay in stickiness. How well do your descriptions agree with what your "snakes" showed?

In the field, soil scientists test soil much as you have done—by rolling a bit of it between their fingers or in the palms of their hands. By testing and comparing many soil samples, they learn to judge well what they call the *texture* of a soil. The texture depends on the proportion of particles of different sizes in a soil, and determines the way a soil feels. Soil scientists name soils according to their texture, and add the name of the place where each soil was first studied: *Ontario silt loam,* for example. When you have read the next section (pages 6 and 7), try to name the samples you studied in the same way. You may decide on such names as *garden sandy loam, ditch silty loam,* or *streambank gravel.*

Kinds of Soil

As you tested your soil samples, you probably discovered that sand grains were the most

Soil "snakes"—*left*, sandy soil; *center*, silty soil; *right*, clay soil

noticeable particles in some, but that some of the finer silt and clay were there, too. In other samples, the finer particles predominated, but you could feel *some* sand. Soil scientists often divide soils into four big classes, according to their predominant (most noticeable) size of mineral particles. These are *gravels*, *sands*, *loams*, and *clays*. Gravels are made up largely of very coarse particles. Sand soils usually contain some silt and clay, but gritty sand particles are most evident. Clay soils may have as little as 30 per cent by weight of clay particles—the rest, silt and sand—but that 30 (or more) per cent is enough to put them in the clay-soil class.

Loams are mixtures of coarse and fine sand, silt, and clay, but each is present in fairly large proportions and no one definitely predominates. Such soils are best for growing most kinds of plants.

Of course, not all gravels, nor sands, nor loams, nor clays are alike. Sometimes it is difficult to decide to which class a soil belongs. In each class, some soils contain more and some less of coarse or fine particles. Take loams, for example. In New York State, five loams are common, each named for its most noticeable particle size (or sizes). These are listed at the bottom of page 8, together with their "texture tests". Some sections of the State have several of these types of loam, some only one. Long Island, for example, has almost entirely sandy loam.

Looking at topsoil

Crumble a lump of moist soil from a plowed garden or field. Does it break into smaller lumps much like crumbs of bread? Look at these crumbs of soil carefully—a magnifying glass will help. Soil scientists call such crumbs *aggregates*, which means *separate things joined together.* The picture on page 10 will help you to understand what aggregates are. Compare the aggregates you examined with bread crumbs. Both have holes, or *pores*, big enough to be seen. In both bread and soil there are many smaller pores that you cannot see.

Water can travel through the soil in these tiny tunnels and in the larger spaces between aggregates. These spaces are important in another way—they let air into the soil. Pores may contain air, or water, or both. Lack of air in the soil is just as bad for most living things as lack of water. If the aggregates have many tunnels and water runs through the soil readily, there is plenty of air in the soil and it is called *well-drained* soil. If there are few tunnels and water stands in the soil, keeping it wet, air cannot get in and the soil is *poorly drained*.

From Agronomy Extension

A soil profile—*above arrow*, topsoil; *below*, subsoil

Humus

Soils are more than mixtures of mineral particles—sand, silt, and clay. The world underfoot is partly air and water, too. Plants and animals, large and small, live and die in it or on it. The waste products and the dead bodies of these plants and animals gradually become part of the soil. Sometimes you can see partly decayed bits of such materials. Small living things in the soil break them down and change them until you can no longer recognize them as leaves or stems or parts of animals. They are only tiny dark-brown or black particles, called *humus*.

Particles of humus are as small as clay. You cannot see them even with the help of a microscope. But they are very important, especially in soils used to grow plants. Humus (and dead plant and animal material that has partially decayed but has not yet become humus) makes soil more porous (full of tiny openings). Soils that contain humus can hold more air and water than soils without it. Humus and the decay of dead plant and animal matter supply growing plants with materials they need to grow well.

Topsoil and Subsoil

Can you find a place where soil has been dug away so you can see what is below the surface? Look in road cuts, new ditches, and places dug out for new houses. Probably you can see that the soil is divided naturally into layers. The darker layer at the surface is called *topsoil*, and the lighter layer underneath is the *subsoil*. In New York State, topsoil is rarely more than 8 inches deep.

Topsoil usually is darker in color than subsoil because it contains more humus. Humus makes the topsoil a good place for seeds to sprout and young plants to grow. Farmers and gardeners work the topsoil.

Subsoil is important, too, because the long roots of many plants take minerals and water from it. Like topsoil, subsoil varies in depth but in New York State is rarely more than 3 or 4 feet deep.

Some New York State Loams

Clay loam	Damp soil rolls into a smooth "snake"
Silty clay loam	Damp soil rolls into a "snake" with cracks
Silt loam	Damp soil rolls into a "snake" which breaks
Sandy silt loam	Damp soil rolls a little but will not hold its shape
Sandy loam	Damp soil will not roll

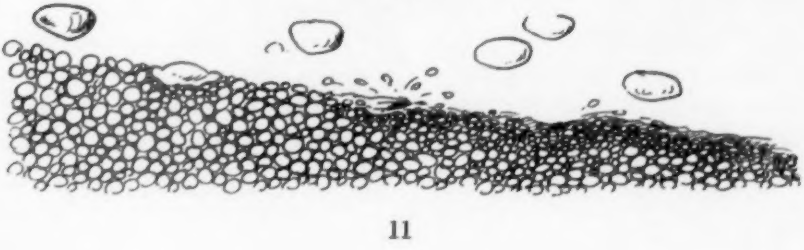
to break. Soil particles may clog the air and water spaces, and plants no longer grow well. If you have potted plants growing in your classroom or at home, you can see for yourself how aggregates are destroyed. With an old fork or spoon, break the soil at the surface of the pots into crumbs. (Be careful not to dig deeply or you will disturb the roots of the plants.) Now, each day water half your pots by pouring water on the surface of the soil. Water the other pots by setting each in a shallow dish and pouring water into the dish. Use the same quantity of water for pots of the same size. At the end of a week or two, what differences do you see in the soil? You may want to continue this experiment for a longer time to see whether the plants grow differently.

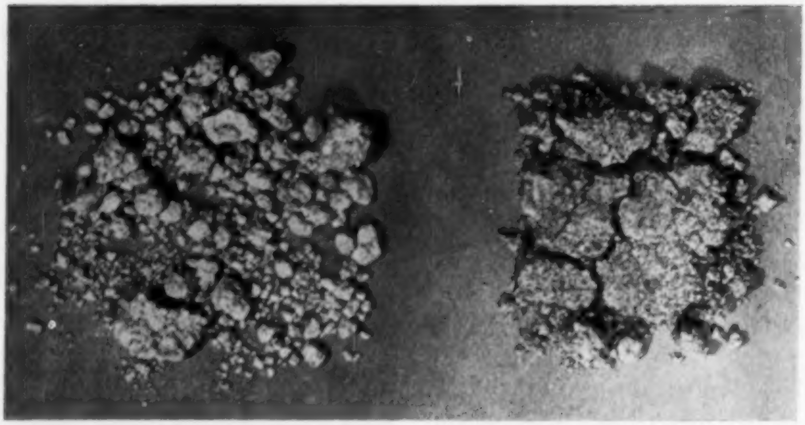
Looking at subsoil

You know that the roots of many plants, such as trees, go below the topsoil. This means that subsoil is important, too. Subsoils in New York State are usually made up of aggregates that are somewhat square. These blocks may be from less than an inch to several feet in height, depth, and width. In dry soil, cracks appear around the aggregates, but moist soil swells and fills the openings so that the structure is difficult to see.

Clay and silt particles are so fine that some are carried by water from the topsoil into the subsoil. If enough clay or silt collects in the subsoil, it may form a clay layer (clay pan) or a silt pan which slows the downward movement of water. This is one cause of poorly drained soil. If the clay or silt layer is not too near the surface, a farmer may drain the soil by putting in tile to carry the water out of the field, or he may grow crops whose shallow roots do not reach below the well-drained upper layers of soil.

The force of raindrops falling on loose, bare soil may break up aggregates and carry away soil particles





Aggregates of various sizes make up the soil shown at the left; in the "puddled" soil at the right, the aggregates have been pushed together, forming a less porous soil

Soil scientists do not completely understand how soil aggregates are made and then held together. Wetting and drying, freezing and thawing help to arrange soil particles to form aggregates. So do the activities of living plants and animals. Groundhogs, moles, insects, chipmunks, and earthworms stir the soil as they dig in it. Plant roots that are growing play a part. The decay of dead plants and animals is also important. After the particles are in position, they are held there by clay and humus. Clay cements larger silt and sand particles together. Humus helps in two ways. It cements larger particles together and it also prevents clay particles from packing too closely. What difference would large quantities of humus in soil make when you try to roll "snakes"?

Soils on which trees or grass have grown for a long time or which have been carefully managed usually have many aggregates. They have many openings through which water and air can move. Roots and root hairs can push their way easily into such soil.

Soils used to grow certain crops often lose these aggregates. Raindrops falling on the bare soil break them, and water that runs off the field carries away more of the silt, clay, and humus than of the larger soil particles. Then, the remaining particles may pack into tight masses or clods that are difficult

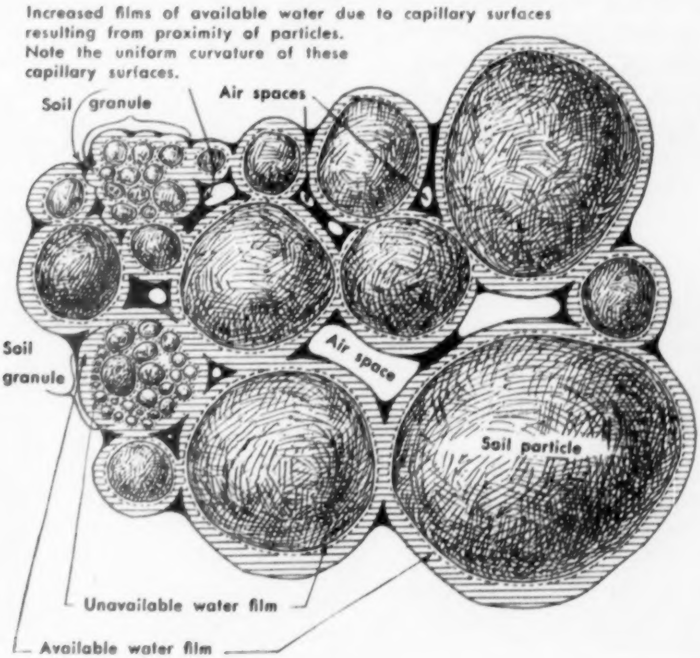
prised to learn that even in soil that *looked* dry and *felt* dry, there was a supply of moisture. It is held so tightly in and on the soil particles that you cannot feel it, plants cannot use it, and usually it will not evaporate.

You know that plants use water in many ways (*Green Factories,* the Leaflet for Winter 1955-56, page 23). You know that most plants get the water they need from the soil through their roots. They get it from water that soaks into the topsoil and subsoil and is held loosely around soil particles and in the soil pores—the spaces between particles and aggregates. Root hairs can absorb this water. The illustration on this page will help you to understand this.

An experiment

You can learn something about how water enters different soils, how readily it passes through, and how much is held. Remember, though, that the soils you will use have been dis-

Soil particles (enlarged), showing how water and air are held in soil



Here, topsoil rests on bedrock, formed millions of years ago at the bottom of a shallow sea

Below subsoil

Broken-up rock usually lies below the subsoil. Often it is difficult to see where the subsoil ends and this *soil material* begins. Even farther down is solid rock. In many places in New York State this bed rock is not far below the surface, but in others it is covered with many feet of soil or soil material. What can you learn about conditions near your home?

Water in the Soil

When rain falls on the soil or snow melts, part of the water runs off, part evaporates into the air, and part soaks in.

Some of the water that soaks into soil soon evaporates into the air, too. Probably you have noticed how quickly the surface of some soils dries after a rain. What kinds of soils dry most rapidly?

Another part of the water that soaks into soil moves (due to the force of gravity) down through the surface layers to lower and lower layers of the earth's rocky covering. There it may become part of the underground water supply that men tap when they dig wells, or that bubbles out in springs. Some of you may wish to learn more about this *ground water*.

Still another part of the water that soaks in remains in the upper layers of the soil—topsoil and subsoil. This is the water supply that is most important to plants and to those who grow plants. As you probably know, many substances dissolve in water. As water moves through the soil, it becomes a *soil solution* (page 28) containing various mineral elements that are present in the soil. Many of these minerals are necessary for plant growth.

When you collected your soil samples, you probably could feel the dampness in some. Perhaps some were so wet that you could see free water. You may be sur-

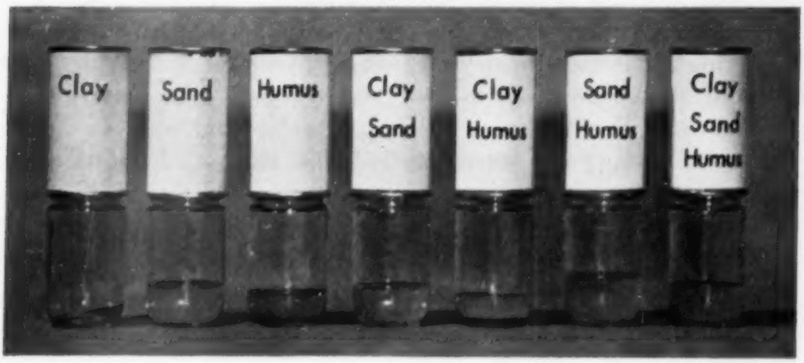
water enter most quickly? Through which soil did water pass most rapidly? most slowly? Which soil let the most water through? Which soil held the most water? What do you think would happen to plants growing in each soil in a very dry summer? in a wet season?

Air in the Soil

Look again at your samples of soil. Can you see anything in the spaces between the soil particles and aggregates? The soil pores look empty, don't they? You can show that there is *something* in those spaces. Dig a lump of soil from a garden or some other bare spot and put it into a glass jar. Add water until it is about 1 inch deep above the top of the soil. Watch carefully. Do you see bubbles coming up through the water? Why does adding water make bubbles? What might these bubbles be? Probably you have seen bubbles rising through liquids before. What are the bubbles in boiling water? What makes bubbles in soda pop? When you read *Green Factories,* did you watch the water plant, *Elodea,* in sunlight and see bubbles rise through the water? What were those bubbles?

The bubbles that you see when you pour water onto soil are air bubbles. Air, whether in the soil or aboveground, is made up of gases. In soil, three of these—oxygen, nitrogen, and carbon dioxide—are especially important. Oxygen is as necessary for living roots and for most plants and all animals that live belowground as it is for animals and plants aboveground. Certain bacteria in the soil can change nitrogen from the soil

Were the results of your experiment similar to these?



turbed, and so do not act exactly as do natural soils out-of-doors.

Get about a pint each of clay and sand. Collect about the same quantity of leaf mold (humus) from under fallen leaves in the woods. Spread each sample separately on newspaper and leave them until all feel dry to the touch. Two or three days should be long enough if you stir the soils occasionally.

Now you will need 7 jars and 7 cans that will just fit on top of the jars. Small frozen-fruit-juice cans and baby-food jars are a good choice. With a thin nail, punch five holes in the bottom of each can. The holes will be the same size if you use the same nail for all. Cut a circle of paper towel to fit the bottom of each can. Put these inside the cans to keep soil from dropping through the holes. Fill each can one-third full, using one of the following soils in each: (1) clay, (2) sand, (3) humus, (4) half sand and half clay, (5) half sand and half humus, (6) half clay and half humus, and (7) one-third each of sand, clay, and humus. Label each can as you fill it. Pack the soil tightly, and place the cans on the jars. If you use small, frozen-fruit-juice cans, pour ¼ cup of water (use a measuring cup) on the soil in the first can. Then fill in the proper column in the record below. Repeat for each can.

Can you now answer these questions: Which soil did the

A record to show how water enters different soils

	Clay	Sand	Humus	Clay, sand	Clay, humus	Sand, humus	Clay, sand, humus
Minutes before all water enters soil							
Minutes before water begins to drip							
Minutes before water stops dripping							
Quantity of water that came through							

- Are both level or about equally sloping? If both are on slopes, do the slopes face the same direction?
- Do much the same kinds of plants grow on each soil—grass or trees or no plants, for example?

Before you take temperatures for study, ask yourself all of the questions in the list except the one which concerns what you wish to study. For example, if you wish to study the effect of sun and shade on soil temperature, you should compare temperatures of places in the sun and of places in the shade. But you should ask yourself all the questions except the one concerning sun and shade to be sure your soils are alike in other ways. You can readily see how many different things can affect soil temperatures and the difficulty of studying just one of these.

Sun on the soil. How much does the sun warm the soil? Find a place where the school, a tree, a house, or a garage casts a shadow. Take the shade temperatures 1 foot inside the edge of the shadow and the sun temperatures 1 foot outside the shadow. Take temperatures in the morning, about noon, and in the late afternoon. What happens to the shadow during the day? Take other temperatures at the same time on different days. Find more places where there are sun and shade and take temperatures. Record your temperatures in a table such as the one below. (You can make a table with more spaces.)

Moisture and soil temperature. Find a place where damp soil and really wet soil are near each other. Use the questions given above to be sure the soils are alike in every way except in moisture. Then take temperatures at the same time on different days and at different times on the same day. Find other places where damp and wet soils are together. Take more temperatures in these places. For each soil, use one

Sun and Shade

Place	Sun or shade	Date	Time	Air temperature	Soil temperatures	
					Surface	3 inches below surface

air into a form that they and other plants can use. You can read about this on pages 26 and 27. Underground plants and animals give off carbon dioxide into the soil air just as aboveground plants and animals add this gas to the air around them. You can see that living things underfoot need a changing air supply. What would happen if the surface of the soil were sealed so that no new air could enter the pores? What happens to air in the soil when water fills all the pore spaces?

Soil Temperatures

When you work in the garden or dig for earthworms on a warm spring day, often you can feel that the soil is cooler than the air. Your hands may even get uncomfortably cold. An inexpensive thermometer or two will help you learn more about soil temperatures and how they differ from air temperatures.

Taking air temperatures. Take all your air temperatures in the same way so that they measure the same thing. Be sure the bulb of your thermometer is dry. Then hold the thermometer by its upper end and away from your body. This keeps the heat of your body and hand from changing the thermometer reading. (If you press your fingers on the bulb and watch the red liquid, you will see how much effect this can have. Now move your hand back a little, then take it away entirely. What happens to the liquid as you move your hand away?) Do not let the sun shine directly on the thermometer bulb. Read the thermometer when the red liquid stops rising or falling.

Taking soil temperatures. Surface temperatures of the soil can be easily taken by laying the thermometer on the ground with the bulb downward. If the sun is shining, shade the bulb with a bent card. To take soil temperatures below the surface, make a slot about 3 inches deep with an asparagus cutter or weed digger or even a sharp stick. Slide in the thermometer bulb and press the soil around the thermometer. Read the temperature as soon as the liquid stops moving.

Comparing temperatures

When you compare temperatures of different soils, be sure you compare temperatures under similar conditions. To decide whether two soils have the same conditions, ask yourself these questions:

Are both soils in the sun or both in the shade?
Are they about equally wet?
Do the soils have about the same texture?

Photo by Doreen Perelli

What differences can you see between the north-facing slope at the left and the south-facing slope at the right?

Plant cover and soil temperatures. It is wise to study the effects of grass and trees on soil temperatures on cloudy days, so that sun and shade will not be a problem. Select places such as a plowed field, a bare spot on the playground, a grassy spot, a place in the woods, or one under a large planting of trees or shrubs on the school ground. Be sure they are as nearly alike as possible in moisture, slope, and texture. Take a number of sets of temperatures and record them in a table similar to those you used for *moisture* and *texture.* Does soil in a woods differ in temperature from bare soil? Does soil under grass differ in temperature from bare soil? What difference in temperature do you find between soil in the woods and soil under grass? Do plants growing on a soil seem to affect its temperature?

What Have You Discovered?

Can you answer these questions from the information in your tables? Is the temperature of soil the same as the air temperature above it? Do sun and shade make a difference in soil and air temperatures? What difference does time of day make? Are temperatures of the soil and air different on different days? Does moisture in the soil influence temperature? Do soil temperatures vary more during a day than air temperatures?

line in a table such as the one below.

When you have taken eight or ten pairs of temperatures (more would be better), compare the temperatures of the damp soils with those of the wet soils taken at the same time. Which soil usually has the lower temperature? Do the air temperatures above the soils differ?

Soil texture and temperature. Do you suppose that clays, silty soils, and sands have different temperatures? Use your thermometers to answer this question. Find places where there are clayey, silty, and sandy soils reasonably close together. Ask yourself all of the questions in the list, except the one about texture, to be sure your soils have similar conditions. Take a series of temperatures and record them as you did when you studied moisture. Can you tell from your record whether fine-textured soils, such as clay, usually have higher or lower temperatures than coarse sandy soils?

Slope and soil temperatures. Farmers often plant peaches, grapes, apples, peas, or other crops on hillsides which face a certain direction. Can you find examples of this near your home? Do you know why one side of a particular hill may be a better place for growing a certain crop than the other side of the same hill? See what you can learn about soil and air temperatures on different slopes. Compare temperatures on slopes which face north with those on slopes which face the south. Are soil temperatures on east- and west-facing slopes the same? Are they different from those on north- and south-facing slopes? You do not need a large hill for this—any terrace or small hill will do. Use the list of questions to be sure all conditions are the same except direction or steepness of slope. Record your findings in a table.

Moisture and Soil Temperature

Place	Soil (damp or wet)	Date	Time	Air temperature	Soil temperatures	
					Surface	3 inches below surface

and moles are *mammals.* Can you name any other New York State mammals that are burrowers in soil? any other animals with backbones (vertebrate animals) that burrow?

A small-game hunt. Nearly every flat rock in woods and fields forms a "roof" over many animal houses. To learn who lives below, lift one of these rocks and look quickly. The animals are often at their "doors," but soon disappear when their roof is lifted. Look under boards, logs, and other such things on the ground. You may want to keep a record of the different kinds and numbers of creatures you find. What was the greatest number you saw under any one "roof"? How many different kinds did you find? Be sure to put the rock or other cover back just as you found it so the animals will still have their homes. You may find slugs and snails, sowbugs, earthworms, centipedes and millipedes, spiders and mites, and several kinds of insects—ants, beetles, springtails, and others. The pictures on this page will help to identify some of your creatures. Most of them get their food in or near the soil. Can you find what they eat? where they get air and water?

Animals in the soil. Get a canful of soil from a garden. Spread

Drawing by Doreen Pere'l

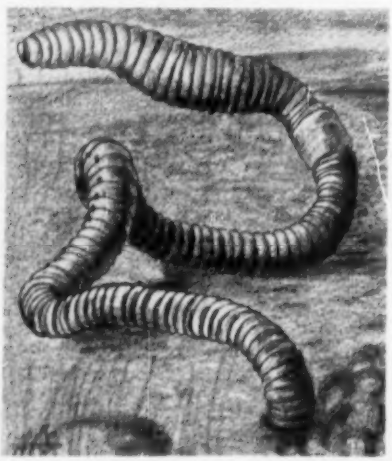
1, slug; 2, sowbug; 3, land snail; 4, springtail; 5, ant; 6, ground beetle; 7, millipede About twice natural size

Life Underfoot

How many plants and animals do you suppose you could find in the soil under just one of your feet? You might see ants, beetles, sowbugs, or an earthworm. Probably you would see plant roots. But there would be billions of microscopic plants and animals that you could not see. A tablespoonful of fertile topsoil may contain more of these tiny creatures than there are people in the whole United States.

How do so many creatures live in the first few inches of soil? You can at least partly answer that question if you make a list of the things that plants and animals need in order to live, and then think back over what you know about soils. In the pores of the soil are air and water. Foods for plants and animals are in the soil, too, or materials from which foods can be made: living and dead plants and animals, and soil minerals. Temperatures below the surface of the soil are usually neither so hot in summer nor so cold in winter as are air temperatures.

Earthworm and earthworm castings (lower right)



Many kinds of plants and animals find ideal living conditions in soil—different kinds in different soils. Many live their whole lives among soil particles. Others live partly in the soil, and partly on or above it, but the soil supplies some of the things they need—perhaps only a place to live. You may want to know more than this Leaflet tells you about these living things and their fascinating lives. Science books and other materials in your library will help you.

Animals underfoot

Many kinds of animals that live in the soil are large enough to be easily seen. A few of these —chipmunks and woodchucks, for example—use the soil as a cozy home, but go aboveground to make a living. Other burrowers, such as moles, spend most of their lives underground, and get most of what they need there. Chipmunks, woodchucks,

bodies usually become humus, too. Sometimes these soil dwellers take dead plant and animal materials down underground, where it, too, may become humus. Earthworms, for example, often pull leaves from the surface into their burrows.

Burrowing animals, large and small, move and often mix soil materials as they dig their way underground. The holes they make let in necessary air and water, and help in drainage. Sometimes roots of plants follow the abandoned tunnels of animals. You can easily see that burrows of animals help to make soils better for growing plants.

Photo by R. B. Fischer

An eastern chipmunk may burrow as much as 30 feet through the soil, and dig as deep as 3 feet

Plants underfoot

By far the larger number of living things in the soil are plants. The tops of many kinds reach up into the light and air above the soil surface. But down below there is often as much of a healthy plant as you can see aboveground—roots and other underground parts.

Below the soil surface, too, are billions of tiny plants. Most of these are too small to be seen without the aid of a microscope. But, as you will learn, they are a most important part of the soil.

Some of these tiny plants (algae of different kinds) have chlorophyll. You learned in *Green Factories* that such plants make their own food. Do you remember what materials they take from the soil and from air? Algae usually live near the surface.

Most of the microscopic plants that live underfoot in soil lack chlorophyll. They must have "ready-made" foods. Most of them get their foods from dead plants or animals. Great numbers of them live in most soils, and there are many kinds. Different soils have different populations. Some of these plants are *molds* or other *fungi* (*fun*-ji; singular, *fung*-gus). Many others are bacteria. Still others, called *thread bacteria* or *actinomyces,* are like molds in some ways, like bacteria in other ways.

Molds and other fungi. You

it at once on a newspaper. Do any small animals wiggle out? Some kinds of insects spend at least part of their lives in the soil—ants, wireworms, and white grubs, for example. Did you find other live animals? Can you find some in the soil in a field? a woods? a damp ditch? other places?

Earthworms. Everyone knows earthworms, especially boys and girls who like to fish. Probably many of you have found earthworm burrows—small holes in the ground with little lumps of dirt around them. These lumps, or *earthworm castings,* are made up of soil and other materials that have passed through the earthworm's body as it fed on substances in the soil. Find some burrows in a lawn if you can. Break a clump of castings in your fingers. Does the soil seem to be glued together? Moisten a casting and rub it between your fingers. Does it feel gritty or smooth? Did the earthworm "eat" sand or only silt and clay? Look for these piles of castings after a hard rain. Does water break the castings much as it broke the aggregates in the flower pots that you watered from the top?

Animals too small to be seen. Among the animals underfoot in most soils are tiny one-celled creatures called *Protozoa,* and small animals called *threadworms, eelworms,* or *nematodes.* Most of them are too small to be seen with the naked eye. You can learn about them from some of the books listed on page 32.

Animals and the soil

Most animals that live in the ground help to build fertile soil, good for growing plants. They help in two main ways: they add humus and they dig holes. Earthworms are particularly important because there are so many of them. To get an idea of how many earthworms there are in a lawn, mark off a square 6 feet long on each side. Look carefully in the grass for earthworm burrows. Count the number in your square. That number, multiplied by 1000, will tell you something of how many earthworms may live in an acre of lawn. Try the same test on hard, bare soil, and on a garden plot. Where did you find evidence of the most earthworms?

Animals add humus to the soil in several ways. As they live in or on the soil, wastes from their bodies are added to it. These materials and bits of uneaten or partly digested foods decay (page 26) and become humus. When animals die, their

grow on rocks, for example, help to break them up into soil materials. Many plants that get their food from dead plant and animal materials—molds and other fungi, actinomyces, and many kinds of bacteria—help to build soil in another, and wonderful, way. As they get their food from whatever they live on, they bring about changes that we call *decay* (page 26). Plants that die, roots left in the soil where crops have grown, and even the bodies of the tiny microscopic plants decay when they die. Gradually these materials become humus, and minerals that the plants had taken from the soil as they grew return to it. Humus is valuable soil material, as you read on page 8. And the minerals returned to the soil can be used again by other living plants. Gardeners frequently help to bring about these changes by making *compost piles* where plant materials are allowed to decay. Do you know anything that farmers often do to add plant materials to the soil where they can decay?

Harmful soil dwellers

Probably no animals or plants are harmful to the soil itself. A few soil dwellers may cause diseases of living things, including man. Some may injure plants that men wish to grow. Moles, for example, eat chiefly insects, but as they burrow they destroy the roots of plants. Snails and slugs are sometimes pests. The grubs of Japanese beetles live in lawns and feed on grass roots. They may spoil a beautiful lawn. Microscopic threadworms (page 22) that live in plant roots may seriously affect the growth of the plants.

Microscopic plants that live in the soil do more damage to crops than do the animals. Some cause plant diseases, such as damping off and root rots. Some injure crop plants by attacking their roots or even their tops. If you plan to grow plants, you may want to learn more about the various ways in which soil dwellers may injure them.

A Japanese beetle grub, about 4 times natural size

Adult Japanese beetle

probably have seen bread mold or the green molds that cause grapefruit and oranges to spoil. Most soil molds are much like these—so small that you can see them with the naked eye only when many grow together. Molds are the most important soil fungi, but yeasts (also microscopic) grow in soils, too. So do some larger *mushroom fungi.*

Bacteria. Bacteria are the most numerous and among the tiniest of all known living things. You could stack thousands of them on a pinhead. In the soil they form colonies on and around the soil particles, wherever food and other conditions are favorable. Most of them get their food from dead plants and animals; but a few are parasites, that is, they live on living creatures. A few can make foods for themselves from certain chemicals. Bacteria known as *nitrogen-fixing* bacteria belong to this group. You can read about them on page 26.

Plants and the soil

If you were to write what the green plants you know best need for growth, you might make a list much like this: (1) something to anchor them in place; (2) warmth enough; (3) light; (4) air; (5) water; (6) certain chemical elements (substances made up of only one kind of atom, you remember). Suppose you use this list, and mark with an S each of these needs that soil supplies, either wholly or in part. Didn't you mark all but one?

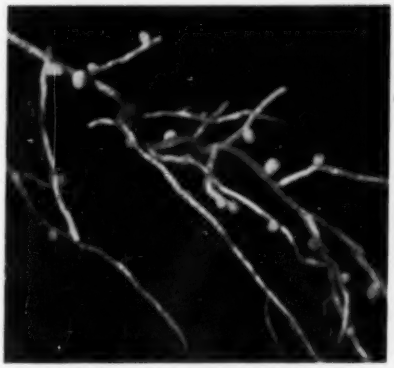
You probably needed to do some research before you could decide about item 6. Did you discover that scientists list about 15 chemical elements known to be necessary for plant growth? Green plants get three of these *essential elements*—carbon, hydrogen, and oxygen—mostly from air and water. But the others (except some nitrogen) are supplied from the solid part of the soil. Ordinary soils contain most of these minerals. Green plants use fairly large supplies of some, but very little of others. You can learn more about this subject on pages 27 and 28, and from books.

Plants *use* soil and certain minerals from it, but they also help to *build* soil. Lichens that

learned in *Green Factories* (page 29) that green plants need nitrogen to make proteins. But green plants cannot use the abundant nitrogen gas from the air. They can use nitrogen only when it is combined with other chemical elements into substances that water can dissolve.

The nitrogen-fixing bacteria *can* use nitrogen from the air. They can combine it with other materials to make foods that they—and other plants—can use. Some of these nitrogen-fixing bacteria live in soil and get the materials they need from dead plant and animal matter. But most of them live in swellings, or *nodules*, on the roots of peas, beans, alfalfa, clover, and some other kinds of plants.

These nodule-bacteria enter the roots through the walls of the root hairs. Masses of giant plant cells form the nodules in which they live. There they combine carbohydrates (sugars and starches, you remember) from the host plant with nitrogen from the air into substances they use as food. The host plant uses some of this food, too. Some diffuses (*Green Factories,* page 19) out into the soil, and some enters the soil when the plant roots die. The usable nitrogen added to the soil by these nitrogen-fixing bacteria is so important that



Nodules on roots of a clover

farmers often grow plants on which the bacteria can live as a part of their crop-rotation program. Many farmers and gardeners treat seed of such plants with cultures of the proper kind of bacteria so that plenty to start nodules will be in the soil around the young plants. Have you known someone who used "bean inoculant" on bean seeds?

Minerals and the soil solution

The rock particles in soils are made up of different minerals, depending on the kind of rock from which they came. And minerals, as you may have learned, are composed of chemical elements, such as aluminum, calcium, copper, iron, or oxygen, or of chemical combinations *(compounds)* of elements. Mixed with the rock particles in most surface soils are dead plant and

Chemistry Underfoot

No one can see the marvelous chemical changes that constantly take place in the soil. Rock particles, water, air, and the plants and animals, living and dead, that make up the soil, all have a part in "chemistry underfoot." It is not easy to understand the changes unless you know a great deal about chemistry. But, if you begin now to think about this subject, you will be ready to learn more about it later. Let's start with three important chemical processes that go on in the soil.

Decay

Probably all of you have had things decay that you wanted to keep and use. Perhaps you think of decay as a wholly harmful chemical process. It isn't, of course. In the soil, decay, caused by living things that get their food from dead plant and animal materials, helps to form humus and to make room and provide necessary minerals for new life.

Can you imagine a world in which dead things did not decay? Leaves that dropped from the trees in autumn would pile up year after year unless fire destroyed them. Fields would be choked with dead plants. The ground would be strewn with fallen trees and littered with animal bodies. Instead, as soon as such things fall to the ground, millions of creatures start to work on them.

A few kinds of soil animals—millipedes, springtails, and earthworms, for example—get their food from such materials. But bacteria, molds, and actinomyces bring about most of the chemical changes that we call decay.

As you might guess, the animals and the tiny plants in the soil that cause decay have different diets. Some get their foods from proteins, some from fats, or starches, or sugars. As one group after another digests what they use, they change their food materials to simpler chemical substances. What one kind (or several kinds) leaves in the soil, another group attacks. Decay is really a gradual, step-by-step process by which many groups of living things get food. They remove dead plant and animal matter from the earth at the same time. And their activities help to form humus and return to the soil and air simple chemical substances that keep soils fertile and supply green plants with necessary materials in a form they can use.

Nitrogen-fixing by bacteria

About 85 per cent of the air we breathe is nitrogen. You

When people use soil to raise crops, they must usually add minerals in the form of manure, lime, and chemical fertilizers. But they need to know what minerals and how much to add—too much of one element may be as bad as too little. Needed materials must be available in the proper quantities.

How Soils Are Made

Soils are made slowly. To make the soil under your feet probably required hundreds of thousands of years. Almost all soil was once solid rock. It takes a long time and many forces to break solid rock into soil particles. But broken-up rock is only the beginning of fertile soil. Humus is needed, too, added slowly as generations of plants and animals live, and die, and decay.

Soil-making goes on and on. New soils are constantly made, and old soils constantly changed. The same forces that have made and changed soil since soil-making began are making and changing soils today: heat and cold; water and ice; wind; living plants and animals; and chemical actions of various kinds, such as dissolving minerals, and humus formation.

You can learn much about soil-making by studying things that happen around you that help to make or change the soil. You can experiment to learn about some of the soil-making forces and processes. And, of course, you can read about this important and interesting process. Here are some suggestions. You probably will discover more things to do.

Some Things to Look For

The work of moving water. Notice muddy creeks and rivers. Look for rock particles deposited when running water slowed, or by waves. Moving water both builds up and tears down soil.

Small landslides.

Worn rocks in old stone walls, or **old tombstones,** weathered by forces you may not be able to name.

Heat and cold and freezing water helped to build this pile of broken rock

Photo by G. D. Harris

animal materials. They, too, are chemical compounds.

Some of these compounds dissolve readily in water, and some do not. (You may have found, by experiment, that water can dissolve many substances.) As soil water moves among the soil particles, some of these chemical materials dissolve in it. It becomes what scientists call the *soil solution*, containing more of some substances than of others, depending partly on how readily they dissolve. You need to know one thing more about the soil solution: it constantly changes as water or minerals are added to or removed from it.

You read on page 24 that green plants get most of the chemical elements they need for growth from the solid parts of the soil. Plants that are not green need certain of these materials, too. But plants cannot use all the chemical elements present in the soil. They can use only those that can be dissolved in the soil solution.

Growing plants take quantities of these soluble compounds from the soil. Some of the minerals in crops that are harvested usually are not returned to the soil from which they came. Water running over the ground or seeping through the soil may dissolve and carry away some minerals and some of the fine clay and humus particles. Two of the minerals that are commonly washed from the soil by water are nitrogen and calcium. In nature much more calcium is lost from the soil than is added to it. Soils which contain little calcium are called *acid* or *sour*. In New York State most soils have lost enough calcium to become acid—some are slightly acid, others moderately acid, and a few strongly acid. Farmers add lime, which contains calcium, to make the soil less acid.

In nature, minerals that are lost from the soil are constantly replaced. By chemical processes, minerals held on clay and humus particles quickly replace some of those taken from the soil solution. Decay (page 26) returns essential elements that can be used by new generations of plants. Some minerals are added slowly from rock particles and humus. Rain water brings small quantities of nitrogen and sulfur from the air into the soil. Bacteria, such as the nitrogen-fixers, add some usable compounds. Under such natural conditions plants can grow on the same soil for hundreds of years, and the soil becomes richer, not poorer.

your tiny "river" during later hard rains? You can learn much about large streams by watching your small one.

Collect waterworn stones

Moving water (or ice) often carries rocks with it. As these rocks, or rocks over which they are carried, grind against each other, they break and wear smooth. Bits that break off may become soil.

Watch wind-blown sand

Place a small heap of dry sand on a windswept sidewalk on a windy day. What happens to it? Does it pile up in some other place? Can you feel sand grains blown against your hand? Wind can move soil, and wind carrying soil can wear away bits of rock.

Experiment with freezing water

Fill a small bottle with water and push a cork into the neck. (Some water should spill out as you put the cork in.) Place the bottle in the freezing compartment of a refrigerator for several hours. Does the cork stand up on a little pedestal of ice like those in the picture? When water freezes it expands (gets larger). The water in the bottle pushed the cork out as it expanded. Water freezing in cracks in rocks may push hard enough to break off pieces.

Photo by R. B. Fischer
What do you think is the story of this "little river"?

Learn by Reading

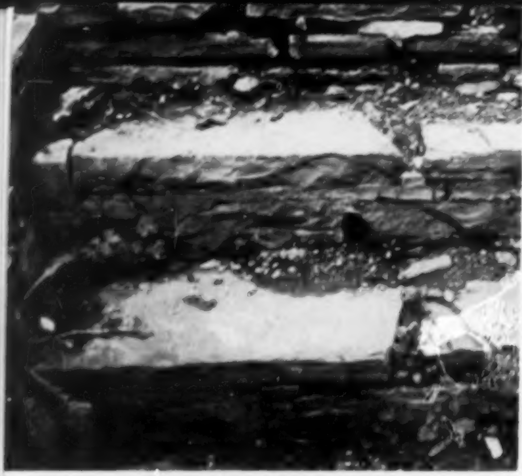
What can you learn about the soils of your home area? of other parts of New York State?

How did great glaciers, moving down from Canada, help to build New York State soils?

Some rocks break down faster than others. Can you discover some reasons for this?

Growing plants for food and other purposes is perhaps our most important use of soil. How can soil be kept fertile?

Much good soil is lost each year by soil erosion. What can we do to save our soil?



What soil-making forces do you think are at work on these stone steps?

Crumbly particles on the surface of boulders. Heating and cooling may be the cause. But lichens growing on rock surfaces may loosen rock particles, too.

Sidewalks broken by the push of plant roots; or cracks in rocks occupied by growing roots.

Heaps of soil near animal burrows. Are topsoil and subsoil sometimes mixed?

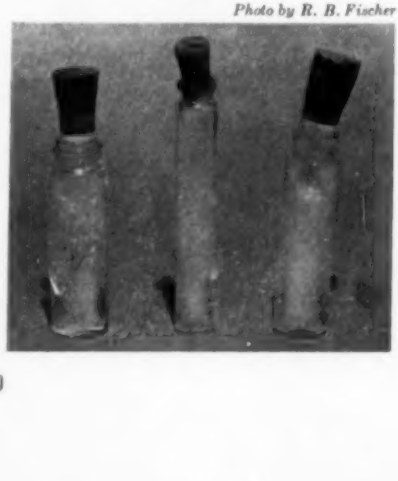
Some Things to Do

Study a little river

After a hard rain look for a sloping patch of bare soil. Newly graded lawns are good places to look. So are the edges of sidewalks. Has water made little "river beds" in the slope? See if you can find where the "river" begins. Does it have tributaries? Can you follow them "upstream" to their beginnings? Now look at the bottom of the river bed. What kind of soil material do you find in the "river bed" near the top of the slope? (Use the texture test, page 6.) What is in the river bed farther down the slope? Where did the water run fastest? (Fast water carries larger soil particles than does slow water.) Examine the end of the "river" at the foot of the slope. What happened to the soil particles that the water still carried? Was the water running faster or slower here than farther up? What does a texture test tell you about the size of particles which the water carried? Are there tiny waterfalls in your stream? Pour water into the "head" of your stream and watch it flow downward. Build dams across the river and its tributaries, using different materials such as twigs, pebbles, soil, and leaves. Pour more water into your stream. What happens to the dams? What happens to

Freezing water pushed the corks out of all three bottles, and cracked the one at the left

Photo by R. B. Fischer



Some Things to Read

Soil. By Bertha M. Parker. Row, Peterson and Company, Evanston, Illinois. 1953 edition. 36 pages. Much information about soils, how soils are made, soil erosion, and soil conservation. Illustrated in color. **The Earth's Changing Surface,** and **Stories Read From the Rocks,** also by Miss Parker, and published by Row, Peterson and Company, are helpful, too.

Conserve Our Soil, Forest, and Wildlife. By D. B. Fales, Hugh Wilson, F. E. Winch, and E. L. Palmer. Cornell 4-H Club Bulletin 77. Mailing Room, New York State College of Agriculture, Ithaca, New York.

The Land We Live On. By C. L. Fenton and M. A. Fenton. Doubleday, Doran and Company, Garden City, New York. 1944. 89 pages. About the earth's surface and its soil. Grade 4 up.

The Land Renewed. By W. R. Van Dersal and E. H. Graham. Oxford University Press, New York City. 1946. 110 pages. Well-illustrated story of soil conservation. Grade 5 and above.

Microbes at Work. By Millicent E. Selsam. William Morrow and Company, New York City. 1953. 95 pages. About many kinds of microbes, especially bacteria, yeasts, and molds. A chapter, *The Living Soil,* is included. Grade 5 and up.

The Story of Microbes. By Albert Schatz and Sarah R. Riedman. Harper and Brothers, New York City. 1952. 172 pages. How microbes live, and how people use or control them. Grade 5 up.

Animals Without Backbones. By Ralph Buchsbaum. University of Chicago Press, Chicago, Illinois. 1948. 405 pages. Well-illustrated. For older readers.

Handbook of Nature Study. By Anna Botsford Comstock. Comstock Publishing Company, Ithaca, New York. 1947. 937 pages. This useful book has a 30-page section on rocks, minerals, and soils. For older readers.

Your library probably has many books and pamphlets that deal with soils and soil conservation. Look in science textbooks, too. Particularly helpful past issues of the *Cornell Rural School Leaflet* are: **Green Factories,** Winter, 1955-56; **The Story of Conservation in New York,** Fall 1952; **Holes in the Ground,** November 1941; and **Save the Soil,** March, 1936. Only **Green Factories** can be sent to you, but those listed and other useful numbers may be in your library.

Cooperative Extension Service, New York State College of Agriculture at Cornell University and the U. S. Department of Agriculture cooperating. In furtherance of Acts of Congress May 8, June 30, 1914. M. C. Bond, Director of Extension, Ithaca, New York.